

WHAT IS CLAIMED IS:

1. A projection optical system, comprising:  
at least one lens;  
at least one concave mirror; and  
5 at least one diffractive optical element.
2. A projection optical system according to  
Claim 1, wherein said at least one lens, said at least  
one concave mirror and said at least one diffractive  
10 optical element have a positive refractive power,  
respectively, and wherein said projection optical  
system does not include a lens having a negative  
refractive power, a mirror having a negative  
refractive power or a diffractive optical element  
15 having a negative refractive power.
3. A projection optical system according to  
Claim 1, wherein said at least one lens, said at least  
one concave mirror and said at least one diffractive  
20 optical element include a lens, a concave mirror and a  
diffractive optical element of a positive refractive  
power.
4. A projection optical system according to  
25 Claim 1, wherein said projection optical system  
includes a first imaging optical system having said at  
least one lens and said at least one concave mirror,

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for imaging an intermediate image of an object, and a second imaging optical system having said at least one lens and at least one diffractive optical element, for projecting the intermediate image onto an image plane.

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5. A projection optical system according to Claim 4, wherein said first and second imaging optical systems are disposed along a common straight optical axis, and wherein abaxial light from the object as reflected and collected by said concave mirror is caused by said mirror to pass through an outside portion of an effective diameter of said concave mirror, toward the image plane side.

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6. A projection optical system according to Claim 4, further comprising a field optical system disposed between said first and second imaging optical systems.

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7. A projection optical system according to Claim 5, wherein said first imaging optical system includes at least a lens having a positive refractive power, said reflection mirror and said concave mirror, which are disposed in the order mentioned above, from the object side.

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8. A projection optical system according to

Claim 7, further comprising a lens group disposed between said reflection mirror and said concave mirror.

5           9. A projection optical system according to Claim 8, wherein said lens group has a negative refractive power and is disposed between said concave mirror and a lens, in said first imaging optical system, having a positive refractive power.

10           10. A projection optical system according to Claim 4, further comprising a reflection surface disposed adjacent an intermediate image formed by said first imaging optical system, and wherein abaxial  
15 light from the object as reflected and collected by said concave mirror is deflected by said reflection surface toward said second imaging optical system.

20           11. A projection optical system according to any one of Claims 1 - 10, wherein at least one of diffractive optical elements of said projection optical system satisfies a relation:

$$3 < MP/\lambda < 50$$

25           where MP is a minimum pitch (micron) of the diffractive optical element, and  $\lambda$  is the exposure wavelength (micron).

12. A projection optical system according to any one of Claims 1 - 10, wherein at least one of diffractive optical elements of said projection optical system satisfies a relation:

5  $|Ld/Lg2| < 0.2$

where Ld is the distance between an aperture stop of said second imaging optical system and said diffractive optical element, and Lg2 is the distance from an paraxial image plane position of an  
10 intermediate image formed by said first imaging optical system, corresponding to an object point position of said second imaging optical system, to an re-imaging plane where the intermediate image is re-imaged.

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13. A projection optical system according to any one of Claims 3 - 10, further comprising a field stop adjacent an intermediate image to be formed by said first imaging optical system.

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14. A projection exposure apparatus for projecting a pattern of a mask onto a substrate by use of a projection optical system as recited in any one of Claims 1 - 13.

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15. A device manufacturing method, comprising the steps of:

exposing a wafer to a device pattern; and  
developing the exposed wafer.

16. A method according to Claim 15, wherein the  
5 exposure step uses laser light from one of an ArF  
excimer laser and an F<sub>2</sub> excimer laser.

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